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DEVELOPMENT AND CHARACTERIZATION OF ALUMINUM 2214 ALLOY WITH USING REINFORCEMENT OF SILICON CARBIDE

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ABSTRACT

The proposed project work is to fabricate and compare the mechanical properties, of Al2214/SiC composites. The composites were processed by using stir casting method and amount of SiC, is assorted from 2-10 wt% in level of 2 wt%.

The prepared composites of Al2214/SiC are to determine the mechanical character such as Microstructure, UTS, YS, Compression Strength, as per the ASTM standards.

The obtained consequence shows that casting was equally distributed without any cracks, voids and discontinues or any faults in the casting. The UTS, YS of the composite was enhanced with the enhance in wt% of SiC and higher compared to ascast aluminium alloy. The compression strength of the developed composites increases marginally with the enhance in wt% of SiC and also the hardness of the composites increases with the enhance in percentage of SiC.

KEYWORDS: Aluminum Alloy (Al2214), Silicon Carbide (SiC), UTS, YS & Compression Strength

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Original Article

1. INTRODUCTION

Aluminium Alloy 2214 material is used in industrial needs and their applications include automobile sectors like pistons, piston heads, and bearings, where the friction and wear rate plays more important role due to its high wt % copper.

The general criteria to choose this series are:

- High mechanical resistance
- High resistance to fissure propagation
- Good workability in tool machines
- Improves its tenacity
- Poor corrosion resistance

The Al 2214-based alloy has physical properties:

Tension Strength >=425

Yield Strength >=275

Hardness 125-145

Table 1: Al 2214 Chemical Distribution

Weight %	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Al2214	Balance	1.2	0.3	5.0	1.2	0.8	0.1	0.25	0.15

Figure 1: Al2214 Ingots.

The Al 2214 material Ingots is a tough aluminum alloy, which is having 1.2 wt% of manganese and other two parameters like silicon and copper as its major alloying elements. Mechanical properties, which enhances the heat treatable alloy as correlated to other Aluminum alloys. It increases high strength, good workability, it improves the good machinability and increases the resistance of corrosion.

The SiC are fine dry particles are in form of powder of size 45-50 µm and it is used as reinforcement in this experimental evaluation, and their mechanical properties of SiC are shown in Table 2.

Figure 2: Silicon Carbide Particulates.

Table 2: Silicon Carbide Mechanical properties

Mechanical Properties	Silicon Carbide (SiC)
Density	3.02 gm/cc
Molecular weight	40.20692 g/mol
Melting Point	1380°C
Vickers Hardness	2800
Crystal structure	Hexagonal crystal structure
Thermal Conductivity	120 W/m. K

The Silicon Carbide is ceramic material and the individual reinforcement Aluminum matrix may constantly adjust to the physical and mechanical behavior. It is very important to find the path to preserve the effective access of SiC while concurrently ministrant to the problems of machining Silicon Carbide MMC's.

The metal matrices composite are achieved by reinforcement of particles to base metal to apprehend the betterment of properties.

To achieve the required properties of MMC's, the reinforcements are used in string, whiskers and chapped. Reinforcement materials are prepared by using liquid metallurgy techniques.

2. OBJECTIVES OF THE RESEARCH WORK

Al 2214/SiC composites are prepared by stir casting method in which quantity of reinforcement such as Silicon Carbide, which varied from 2-10 wt% in every variation of 2 wt%, of SiC assorted from 2-10 wt% in steps of 2 wt%, Microstructural studies of Al2214/SiC composites by using SEM, to know the presence and distribution of particulates.

Microstructural analysis of Al2214/SiC composites by using EDS/XRD to confirm the SiC phase.

To characterize developed Al2214/SiC composites for various mechanical characterstics such as tensile and compression by using Universal Testing Machine.

3. PREPARATION OF MMC's

The Al2214 alloy was used as matrix alloy and SiC was used as reinforcements for development of composites. SiC of 2-10 wt. % (interval size 2%) the value is reinforced with the Al2214/SiC composites.

The Melting pot containing with impeller is made up of stainless steel and hence aluminum coating is done to impeller and ensured maintaining at the rotation speed of 400-600 rpm.

The pure magnesium of 3kg was melted with cleanliness. To avoid oxidation, the degasser are used to create inert atmosphere and removes the lava from the Al2214 molten.

During arousing, the preheated SiC was poured in to the molten metal and mixed equally. Once arousing was completed, the furnace was tilted and ready molten metal was poured into the die.

Table 3: Composition of Specimens Reinforced

Specimen	Al2214 (gm)	SiC (gm)	Wt.%
A	2000	0	0
B	1960	40	2
C	1920	80	4
D	1880	120	6
E	1840	160	8
F	1800	200	10

3.1 Stirring Procedure

From the Figure 3, it shows that the temperature-time curve indicating the temperature excursions are used in these experiments.

There are different steps of processing

Phase 1: Molten metal furnaces are maintained for 60 min in atmosphere condition.

Phase 2: The stirring temperature of the molten metal are brought up to 700°C.

Phase 3: The molten metal in the semi solid phase for 5 min.

Phase 4: The composites were re-melted to a temperature above the liquid temperature up to 700-720 °C for 10 min as per temperature time curve.

Phase 5: The ready molten metal is cascade into the cast-iron die and cooling to room temperature for 15 min.

Table 4 Stirring Parameters

Stirring Temperature	Stirring Speed	Stirring Time (Seconds)
675°C	500 rpm	600 seconds

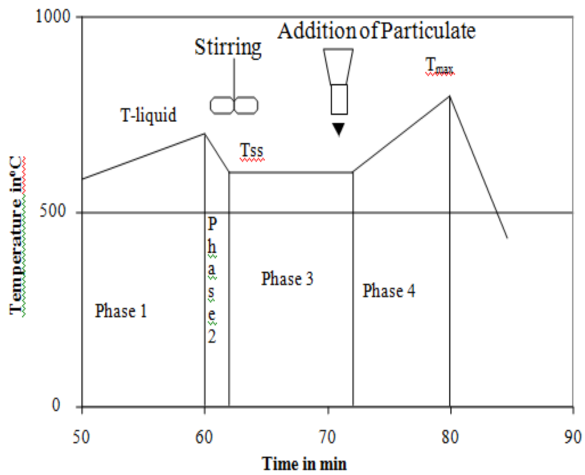

Figure 3: Temperature-Time Curve for Composite Preparation.

4. CHARACTERIZATION OF Al 2214 SiC MMC's AND ANALYSIS

4.1 Microstructure Studies (ASTM F2450-04)

The optical microscope remains the most important tool for the study of microstructure.

The casting workpiece were removed from the molding die and it is cut as per dimensions with the help of cutting machine. The machining operation as to be done for conducting experiment and care was taken to prevent cold working of the metal, which can alter the microstructure and complicate the interpretation of constituents.

The rough polishing is done by series of abrasive belts made up of SiC sand belts. The polishing specimen was done in two stages, rough polishing and finish polishing.

To study the microstructure the optical microscopes are used to find the structure of matrix and composite surfaces. The testing of structure starts with use of the optical microscope begins with a low magnification, from 100 X it followed by progressively to higher magnifications up to 400X to assess the SIC characteristics.

The expediency of liquid metallurgy method is to produce Al-based composite containing SiC was confirmed. The incorporation of SiC in the Al 2214 matrix was successful in all the castings.

4.1.1 The Samples of Al2214 and Al2214+SiC MMC's

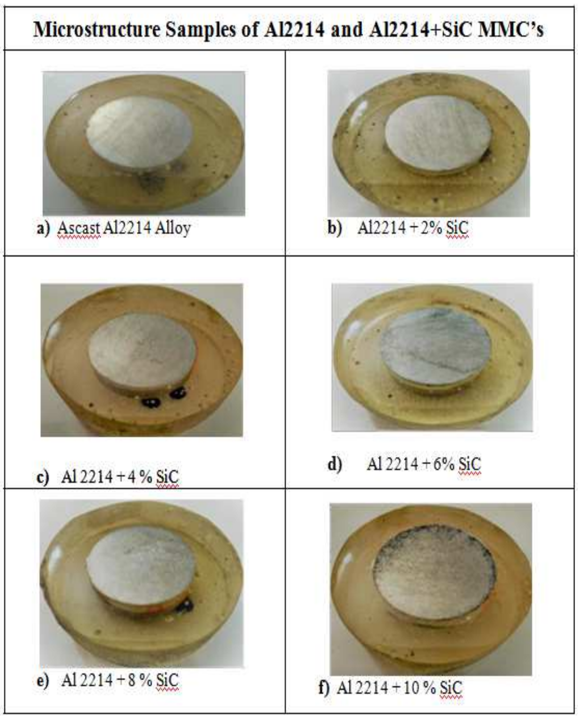

Figure 4.1: Microstructure Specimens for Optical Microscopy Test a) Ascast Al2214 Alloy, b)Al2214 + 2% SiC, c) Al 2214 + 4 % SiC, d) Al 2214 + 6% SiC, e) Al 2214 + 8 % SiC f) Al2214 + 10 % SiC

4.1.2 The Microstructure Studies of Al2214 and Al2214+SiC MMC's

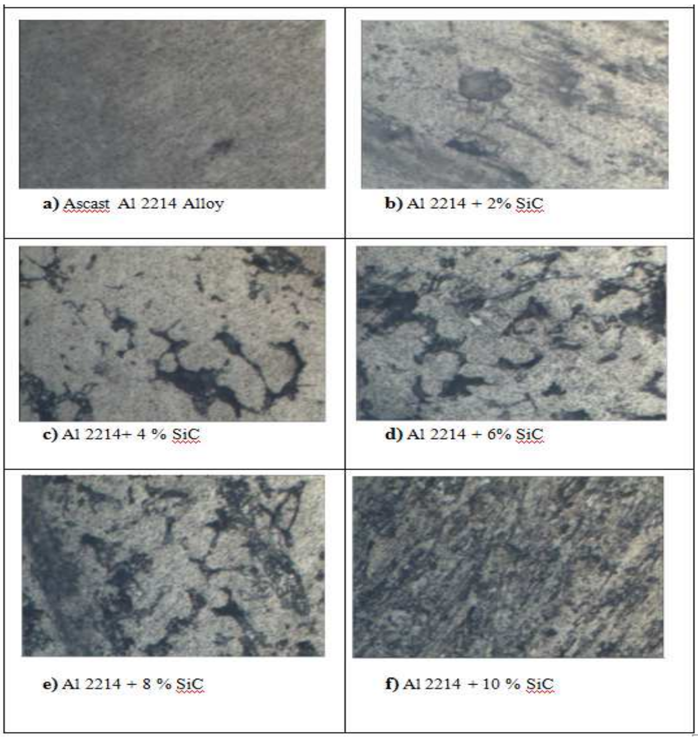

Figure 4.2: Microstructure Specimens for Optical Microscopy Test a) Ascast Al2214 Alloy, Al2214 + 2% SiC, c) Al 2214 + 4 % SiC, d) Al 2214 + 6% SiC, e) Al 2214 + 8 % SiC f) Al2214 + 10 % SiC

From the Figure 4.1, it shows the arrangement of reinforcing particles and its apportionment has a major impact on the properties of particulate composites. The specimens were prepared for microstructure analysis by evenly polishing and engraving.

The polished samples were checked under an optical microscope for examining the microstructure as shown in fig 4.2 gives the microstructure of a) Ascast Al 2214 Alloy, b) Al2214 + 2% SiC, c) Al 2214 + 4 % SiC, d) Al 2214 + 6% SiC, e) Al 2214 + 8 % SiC, f) Al 2214 + 10 % SiC. The composites arranged under the same condition, which shows the equal administration of the reinforcement in the matrix.

The properties of physical and mechanical depend on the structure of specimen and particle size, shape and state of arrangement.

It is concluded that the presence of SiC Particulates and the grid grain surface is larger in matrix alloy compared to MMCs. There were few large clumps of SiC within some patches of the grid while other areas were entirely SiC devoid.

The composites prepared under the identical condition, which shows the even distribution of the reinforcement in the matrix. The structure of Al2214 and Al2214+SiC MMC's samples were noticed under an optical microscope for examining the microstructure as shown in figure 4.2.

4.2 Tensile Test of MMC's

4.2.1 Samples (ASTM E8)

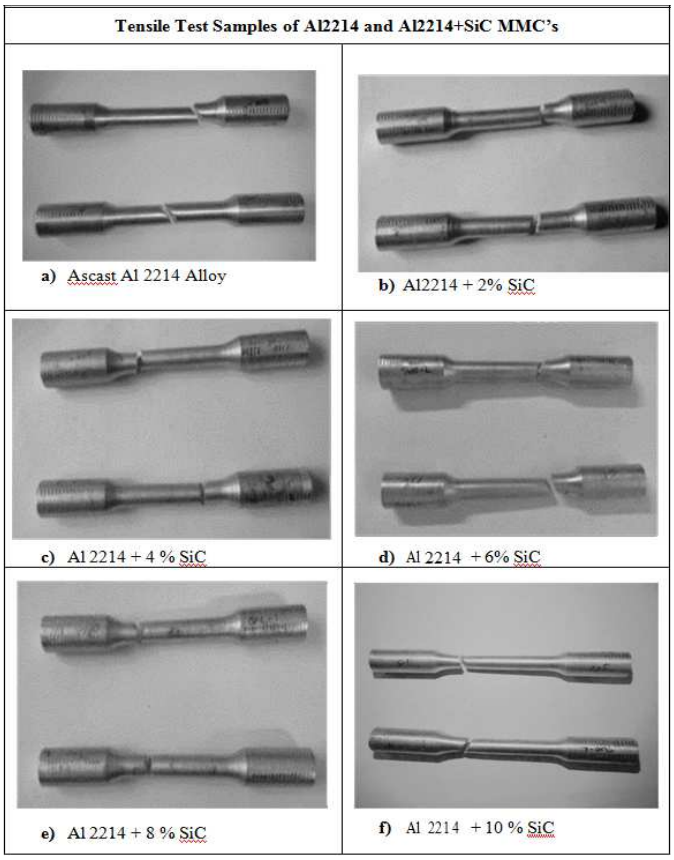

Figure 4.3: Tensile Test Specimens of a) Ascast Al 2214 Alloy, b) Al2214 + 2% SiC, c) Al 2214 4 % SiC, d) Al 2214 + 6% SiC, e) Al 2214 + 8 % SiC, f) Al 2214 + 10 % SiC

4.2.2 Ductile Test (UTS and YS)

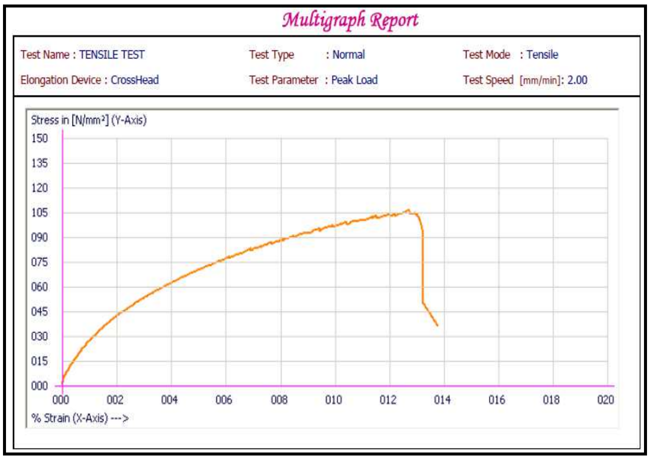

Figure 4.4: Typical Stress v/s Strain Graph of Tensile Test for Al2214 Alloy.

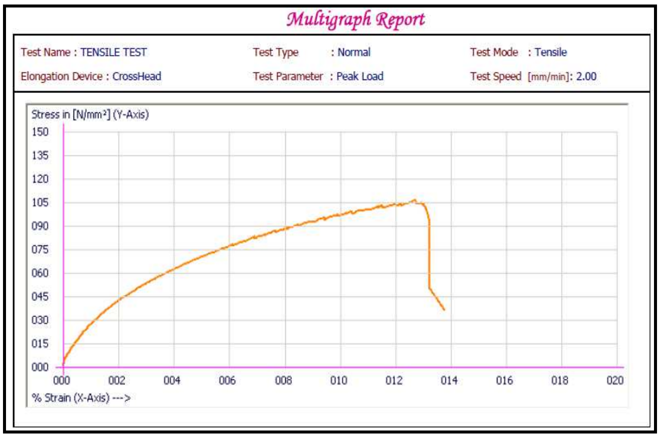

Figure 4.5: Typical Stress v/s Strain Graph of Tensile Test for Al2214+2 wt.% SiC.

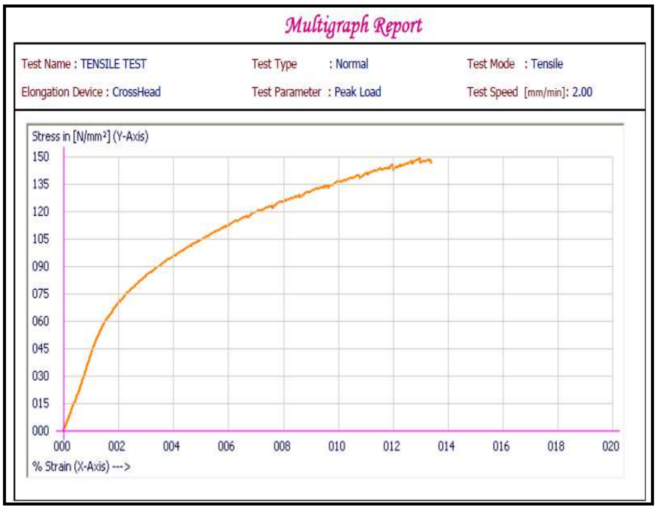

Figure 4.6: Typical Stress v/s Strain Graph of Tensile Test forAl2214+4 wt.% SiC.

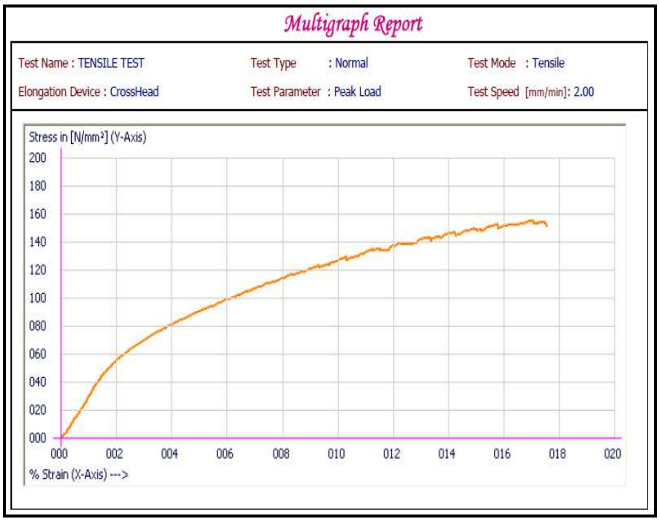

Figure 4.7: Typical Stress v/s Strain Graph of Tensile Test for Al2214+6 wt.% SiC.

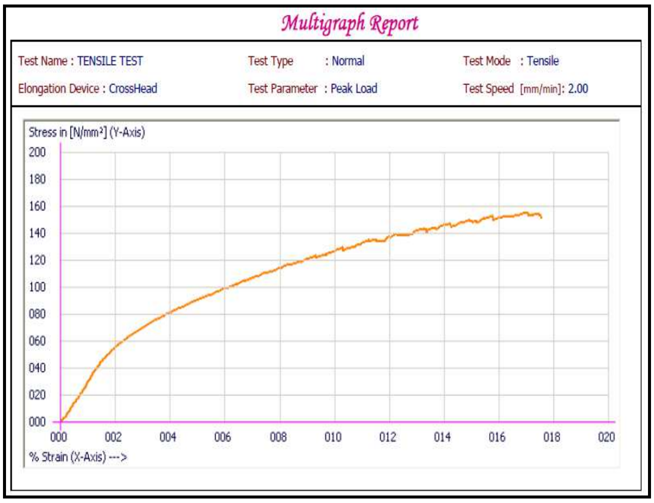

Figure 4.8: Typical Stress v/s Strain Graph of Tensile Test for Al2214+8 wt.% SiC.

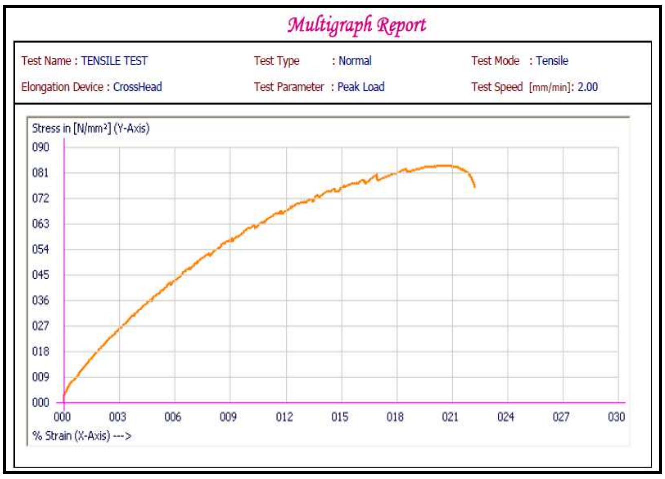

Figure 4.9: Typical Stress v/s Strain Graph of Tensile Test for Al2214+10 wt.% SiC.

Table 4.1: UTS and YS for Al2214 and Al2214/ SiC Metal Matrix Composites.

Sl. No	Wt.% of Reinforcement	Yield Strength N/mm^2	Ultimate Tensile Strength N/mm^2
1	Al 2214	86.46	117.63
2	Al2214 + 2% SiC	96.27	130.71
3	Al 2214+ 4% SiC	106.06	148.51
4	Al 2214 + 6% SiC	116.72	154.76
5	Al 2214 + 8% SiC	119.65	156.27
6	Al 2214+10% SiC	37.29	83.39

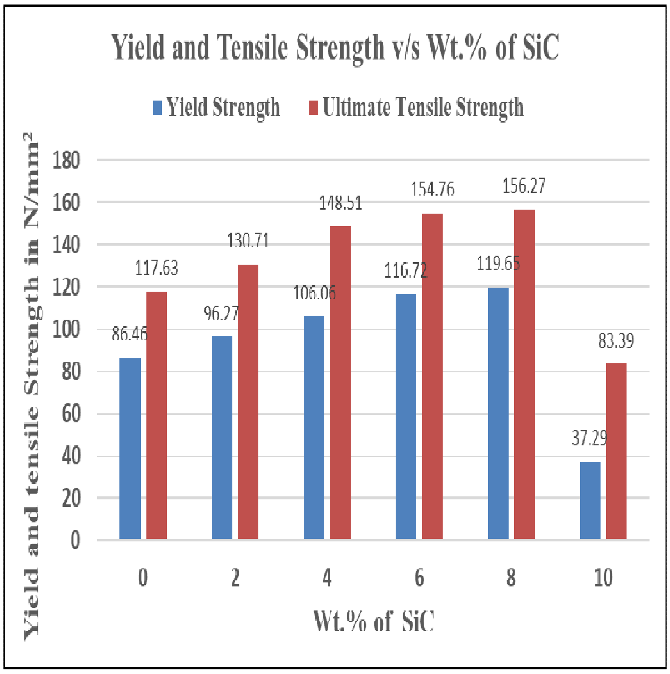

Figure 4.10: Wt.% of SiC on UTS and YS for Al2214 and Al2214/SiC Composites.

The figures 4.4 to 4.9 shows the typical Stress v/s Strain graphs of tensile test for Al2214 alloy and Al 2214+ (2 -10 wt.% of SiC) composites and table 4.1 presents the average values of UTS and YS of aluminium alloy and its composites. Figure:4.10 shows the combined graphs for the effect of reinforcement content on UTS and YS of the processed Al 2214 + (2 -10 wt.% of SiC) composites. Evaluate each value of UTS is an average of two experiments.

It is noticed that from the Figure 4.10 shows the betterment of UTS and YS was occurred up to 8 wt. % SiC, and as enhanced percentage of SiC content to 10 wt.%. There is an abrupt drop in the UTS and YS. As the SiC presence is higher it led to clump formation and disruption and de-bonding between the matrix and reinforcement.

The weight percentage of SiC is enhanced from 0 to 8 wt.%, the UTS is enhanced by about 24.72 % and YS by 27.73 %. The enhanced in UTS and YS improves the presence of hard SiC particulates and that improves the strength of the matrix alloy, thereby providing enhanced resistance to tensile stresses.

5. COMPRESSION TEST OF MMC's

5.1 Samples (ASTM E9)

From the cast composites as per the ASTM E9 standard, the size of specimen of 12mm diameter and 20 mm length for the compression tests were conducted using universal testing machine

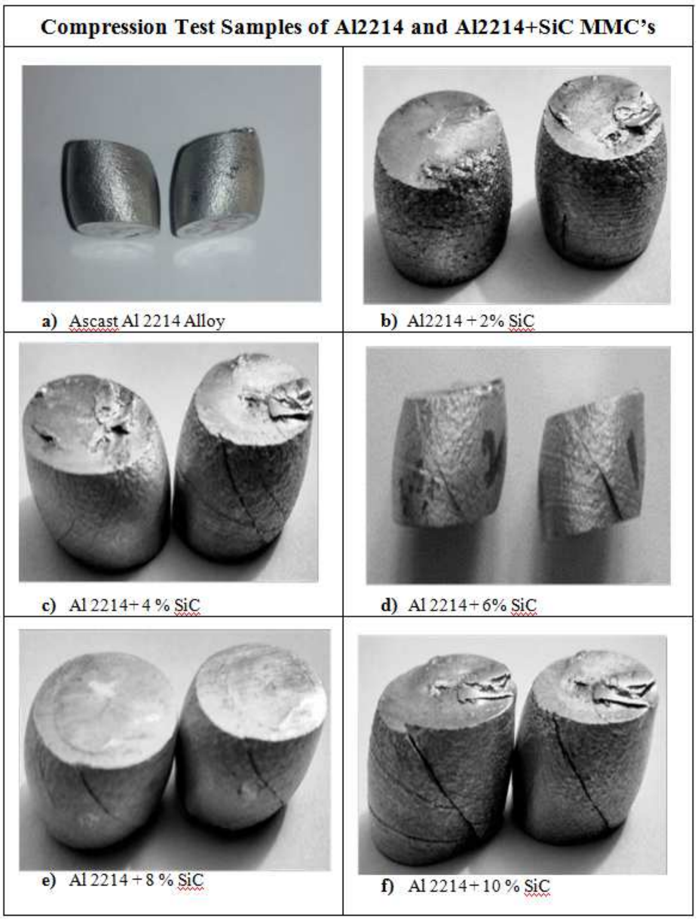

Figure 5.1: Compression Test Samples of a) Ascast Al 2214 Alloy, b) Al2214 + 2% SiC, c) Al 2214 +4 % SiC, d) Al 2214 + 6% SiC, e) Al 2214 + 8 % SiC, f) Al 2214 + 10 % SiC

5.2 Compression Test Strength and Ultimate Load

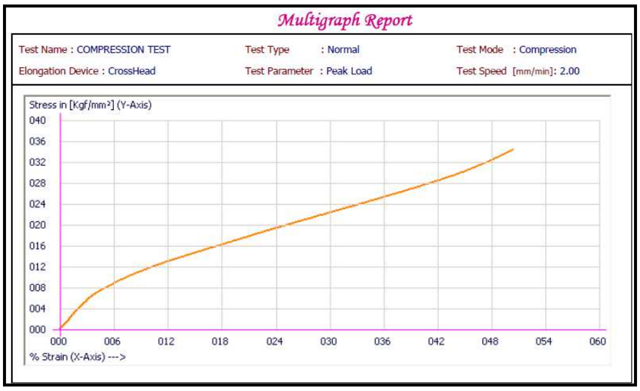

Figure 5.2: Typical Stress v/s Strain Graph of Compression Test for Al 2214 Alloy.

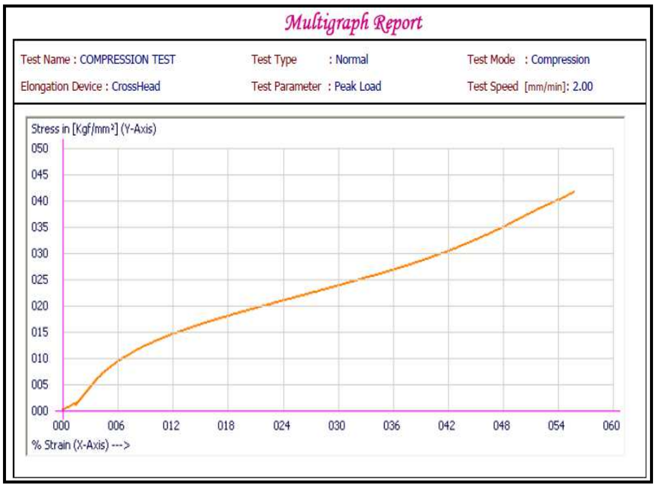

Figure 5.3: Typical Stress v/s Strain Graph of Compression Test for Al 2214+2 wt.% SiC.

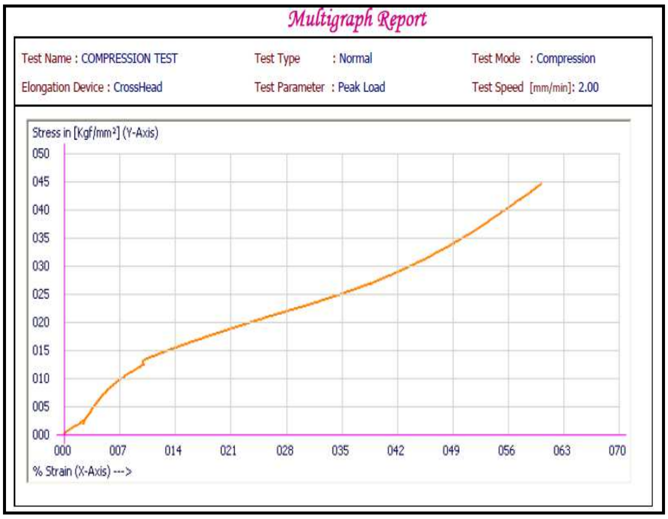

Figure 5.4: Typical Stress v/s Strain Graph of Compression Test for Al 2214+4 wt.% SiC.

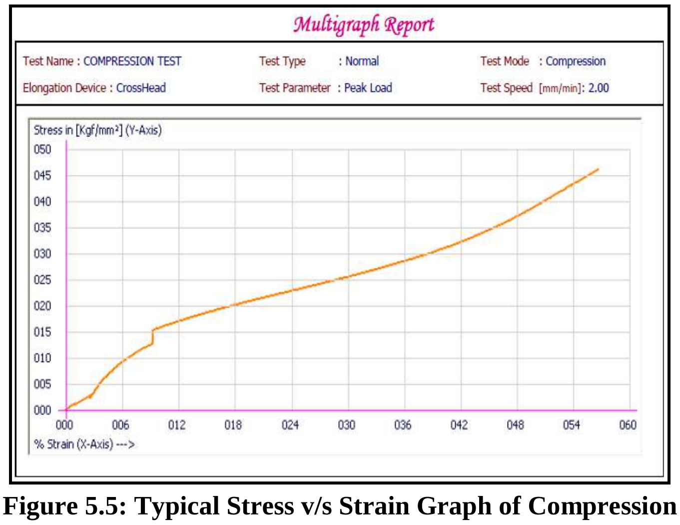

Figure 5.5: Typical Stress v/s Strain Graph of Compression Test for Al 2214+6 wt.% SiC.

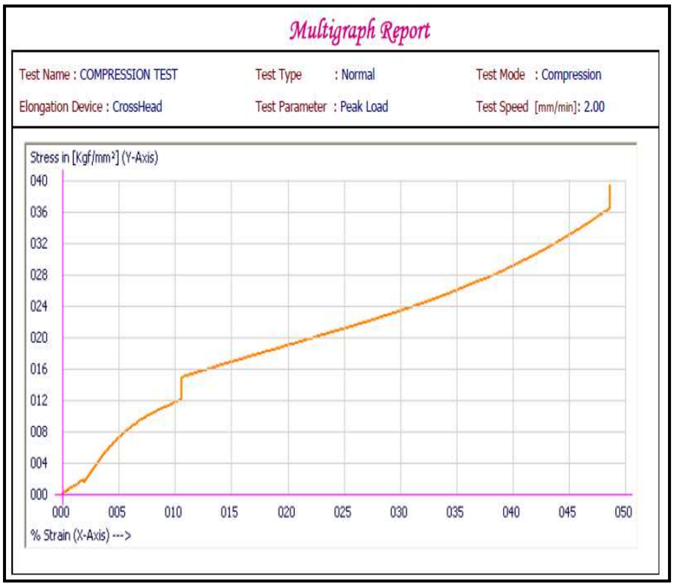

Figure 5.6: Typical Stress v/s Strain Graph of Compression Test for Al 2214+8 wt.% SiC.

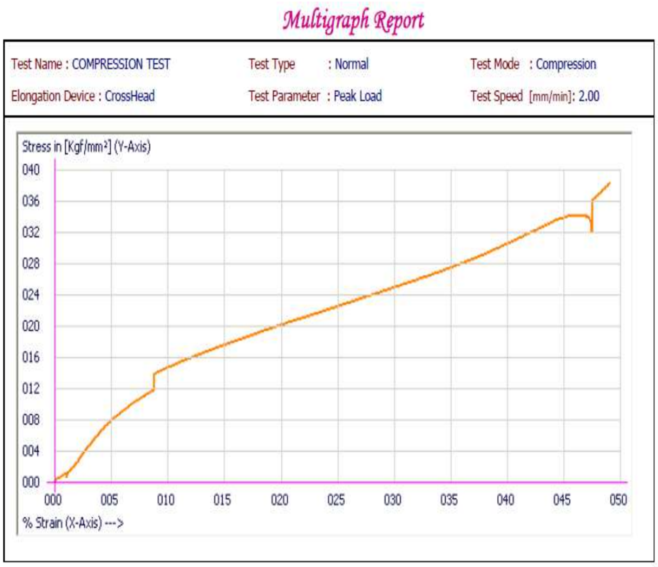

Figure 5.7: Typical Stress v/s Strain Graph of Compression Test for Al 2214+8 wt.% SiC.

Table 5.1: Compressive Strength and Ultimate Load for Al2214 and Al2214/ SiC Metal Matrix Composites

Sl. No	% of Reinforcement	Compressive Strength N/mm^2	Ultimate Load N
1	Al 2214	360.68	25348.83
2	Al2214 + 2% SiC	384.26	28180.12
3	Al 2214+ 4% SiC	420.25	33456.93
4	Al 2214 + 6% SiC	449.66	37138.21
5	Al 2214 + 8% SiC	475.26	39225.31
6	Al 2214 +10% SiC	390.82	31909.71

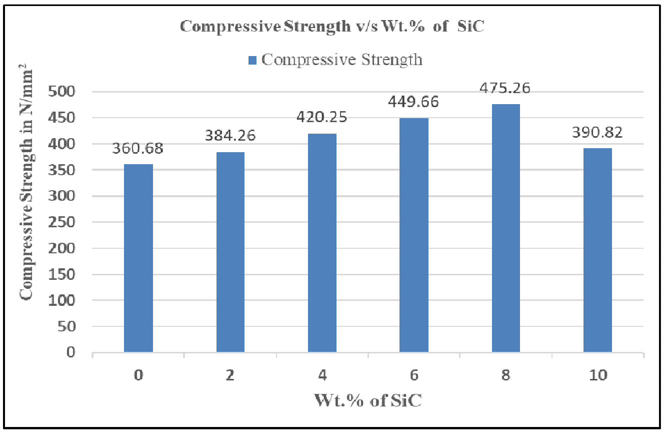

Figure 5.8: The Effect of Wt.% SiC on Compressive Strength of Al2214 and Al2214/ SiC Composites.

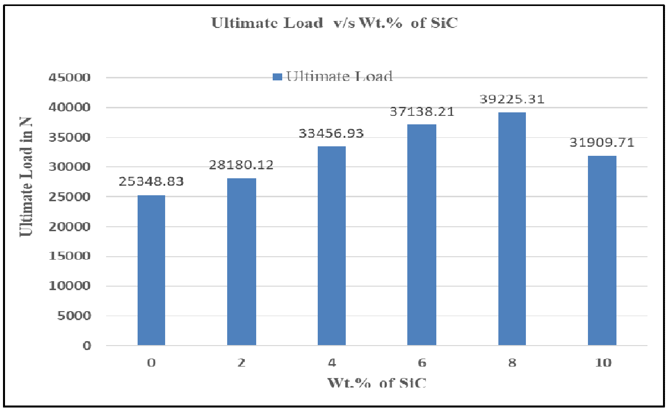

Figure 5.9: The Effect of Wt.% SiC on Ultimate Load of Al221 and Al2214/SiC Composites.

The figure 5.2 to 5.7 shows the typical Stress v/s Strain graphs of Compression test and represents the compression test samples for Al 2214 alloy and Al 2214 + (2 -10 wt.% of Silicon carbide composites and table 5.1 presents the average values of compressive strength and Ultimate load of alloy and its composites.

Figure 5.8 and 5.9 shows that the compressive strength and ultimate load of the composites is higher than that of the base Al 2214 alloy due to the presence of hard Silicon carbide particles. The Silicon carbide particles have higher compressive strength than the matrix. Hence, an increase in compressive strength is observed with enhancing wt.% of Silicon carbide and also enhanced in ultimate compressive load is observed with enhancing wt.% of Silicon carbide reinforcement.

It is noticed that at 10 wt.% of Silicon carbide reinforcement, which is said to be reduced by 17.76 %, as shown in Figure 5.8, there is a drastic reduction in compressive stress and also the ultimate load by 18.65 % its due to the clump development and mainly because of disruption and loosening between the grid and reinforcement.

The weight percentage of Silicon carbide is enhanced from 0 % to 8 wt.%, the compression stress is enhanced by about 23.47 %, and also the maximum load carrying capacity of the composites is enhanced by 35 %. Since silicon carbide is more tougher than the grid. The tough substances restrain abrasion force by enhancing the compression stress of the composite. Though, the addition of Silicon carbide particulates has made the metal matrix composites to behave as fragile rather than adaptable substances, as is observed from the above results.

6. CONCLUSIONS

The samples of composites shows equal and systematic dissemination of reinforcement particulates in the Al2214+2 to 10 weight percentage of Silicon carbide MMC'S.

As weight percentage of SiC is up to 8 wt. % due to no clumps and also it is observed that there is good bonding among grid and reinforcement particles, which helps in more load transfer from grid to reinforcement material. Few clumps, disarray and debonding mechanism are formed when silicon carbide particles are enhanced to 10 wt.% which results in drop out of the mechanical and wear properties of this composites.

It is observed that at 8 wt. %, of silicon carbide, the betterment of UTS and YS was achieved thereby providing enhanced resistance to tensile stresses. At 10 wt. percentage Silicon carbide content was enhanced there is a drastic decrease in the UTS and YS as due to clump formation and because of disruption and de-bonding between the matrix and reinforcement.

At 10-weight percentage of silicon carbide from the Figure 5.8 and Figure 5.9 shows that there is drastic decrease in compressive stress and it reduces by 17.76 %, and also reduction in the maximum load by 18.65 % is because of the clump formation and due to dislocation and debonding between the matrix and reinforcement.

From the Figure 5.8 and Figure 5.9, it is observed that SiC is enhanced from 0 % to 8 wt.% and the compression stress is enhanced by about 23.47 %, and also the maximum load carrying capacity of the composites is enhanced by 35 %. As silicon carbide is much tougher than the matrix, The tough particles resist abrasion stress while enhancing compression strength of the composite. Though, the addition of silicon carbide particulates has caused the metal matrix composites to behave as delicate rather than amenable materials, which is noticeable from the above results

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